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1.B Characterization of Microchannel-Plate Detectors for High-Speed, Gated X-Ray Imaging by Electro-Optic Sampling

A widely used device for diagnosing laser-driven, inertial-confinement-fusion experiments is based on the high-speed, x-ray gating of a proximity-focused microchannel-plate (MCP) detector.[1] This device was described in article 1.A of this volume. The MCP is a nonhomogeneous air/glass dielectric medium that provides extremely high (nonlinear) electron gain. For gating applications, a microstrip line (see Fig. 53.1, article 1.A of this volume) is fabricated by coating a 1- to 6.55-mm-wide, 500-nm-thick Au/Cu center conductor on the front and a 500-nm-thick Au/Cu ground plane on the back of the MCP. A short (<100-ps) high-voltage pulse is propagated along this microstrip, resulting in a localized gating on the MCP wherever the voltage is applied (Fig. 53.12). Obviously, the exact knowledge of the pulse-propagation characteristics (e.g., propagation velocity, attenuation, bend-induced dispersion, etc.) is critical to the optimal design of the MCP x-ray detector and correct analysis of the obtained experimental data.

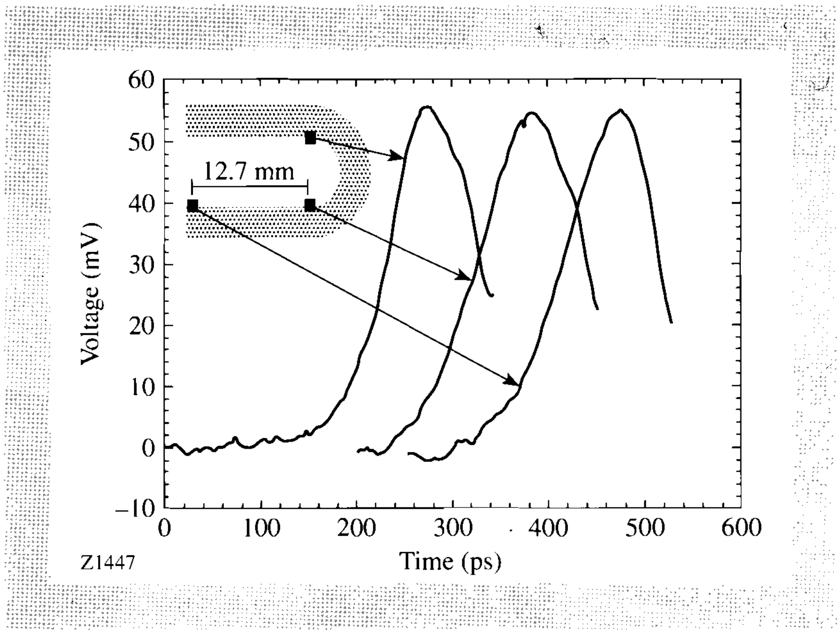

Fig. 53.12
Experimentally measured waveforms sampled before and after the pulse entered the MCP serpentine bend. The input pulse was ~100 ps wide.

In this article, we present a picosecond characterization of the MCP microstrip detector. Our measurements were performed using the electro-optic sampling system described in detail in Ref. 2. Briefly, a photoconductive switch was illuminated with ~140-fs-wide laser pulses (λ = 750 nm), produced by a commercial (Mira 900), mode-locked, Ti:Al_2O_3 laser. The switch was formed in a microstrip transmission-line configuration and was coupled to the MCP microstrip line. This arrangement produced 20- to 100-ps-wide electrical pulses, which were launched onto the MCP transmission line. The propagated pulses were *externally* sampled at different positions along the line with a $LiTaO_3$ finger probe positioned near the conductor edge.

We have found (see Fig. 53.12) that ~100-ps-wide pulses propagated along the microstrip serpentine transmission line without any significant attenuation or pulse distortion. On the other hand, shorter pulses exhibited substantial degradation, even before entering the first bend. Figure 53.13 shows the ~20-ps-wide waveforms sampled at intervals of 2.54 mm along the MCP detector. We observed that in this case the signal rise time increased as the waveform propagated along the line, indicating signal dispersion. Simultaneously, the peak voltage of the propagating pulses decreased.

The measured electrical transients allowed us to determine the signal arrival time, taken to be the midpoint of the rising edge. Based on our measurements, we calculated the signal-propagation velocity, which varied from 0.52 to 0.65 of the speed of light, depending on the line dimensions and MCP porosity. The propagation velocity, in turn, allowed us to determine the line-characteristic impedance and the relative dielectric constant, which was found to range from 2.46–4.08.

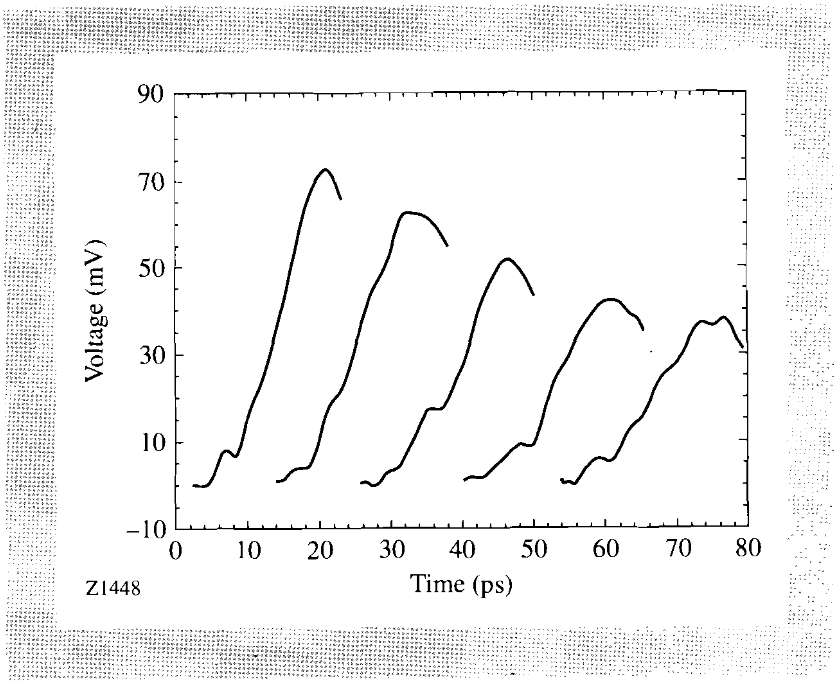

Fig. 53.13
Experimentally measured waveforms sampled every 2.54 mm. The input pulse was ~20 ps wide.

In conclusion, electro-optic sampling was applied, for the first time, in the characterization of MCP x-ray detectors, used in diagnosing laser-driven fusion implosions, both on the OMEGA laser system at LLE and on the NOVA laser at LLNL. We have shown that the transient characteristics of the MCP microstrip can be readily extracted from our waveform measurements, providing important information about the MCP detector operation. The described experiments also demonstrated the feasibility of very accurate time-domain characterization of millivolt-level picosecond signals propagating on very-low-impedance microstrips, such as those often found in GaAs microwave devices and Si-based superconducting digital circuits.

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